United States Environmental Protection Agency **Office of Research and Development**

National Exposure Research Laboratory
FY02 Research Abstract

Government Performance Results Act (GPRA) Goal 1
APM 60

Significant Research Findings:

Preliminary Results of Modeling Airborne Toxic Pollutants and PM at Neighborhood Scales

Scientific Problem and Policy Issues

Air quality (AQ) simulation models provide a basis for developing and implementing the National Ambient Air Quality Standards (NAAQS) and are being used as tools for performing risk-based assessments of air toxics and for developing and testing environmental management strategies. Spatial and temporal patterns of fine particulate matter ($PM_{2.5}$) and airborne air toxic pollutants vary considerably across urban areas and under different geographical and climatic regimes. For human exposure assessments, AQ models should be capable of simulating the features observed on neighborhood-sized scales (~1 km), especially for those situations where pollutants exhibit a high degree of spatial and temporal variability. Meanwhile, exposure models need to be able to handle concentration fields that have been resolved to the neighborhood scale level when they are used for addressing issues such as environmental justice, community-based risk assessments, and hot spot analysis. Previous versions of the U.S. Environmental Protection Agency's state-of-the-art Models-3/Community Multiscale Air Quality (CMAQ) modeling system were able to simulate the meteorology and complex chemistry associated with fine-particulate and toxic pollutants at spatial resolutions ranging from 36 to 4 km (i.e., regional to urban scales). However, human exposure models continue to be driven using either limited amounts of monitoring data or crude dispersion modeling tools. Thus, rigorous chemical transport models (like CMAQ) need to be extended down to a spatial and temporal scale necessary for accurately simulating neighborhood scale features (about 1 km) for use by human exposure models.

Research Approach

In this study, we explore the requirements for modeling air quality at neighborhood scales to enable human exposure assessments at the community level. Our approach is to investigate the science and operational requirements for running CMAQ at ~1 km grid resolution. Additionally, we suggest methods to handle the concentration variability due to within-grid sources and atmospheric processes that are not directly resolved by the model. Recognizing that much of the attention for exposure assessments will be focused in urban areas, it is important to ensure that the flow fields in urban areas are accurately simulated, taking into account the effects of heterogeneous building features in urban areas.

In this study, a prototype urban canopy parameterization (UCP) is introduced into the NCAR-PSU Mesoscale Model Version 5 (MM5) at a fine-scale resolution (~1 km horizontal grid spacing). (The MM5 provides the meteorological fields for the chemistry-transport model in CMAQ.) The UCP is an approach to describe the impact that buildings and other urban structures have on the winds and temperatures in each of the grids. The UCP is applied to all grid cells in MM5 that have some fraction of land classified as urban. For this investigation, a model domain and study area centered on the Philadelphia metropolitan area was established, and the MM5/CMAQ model system was run for simulations at horizontal grid dimensions of 36, 12, 4, and 1.33 km, the smallest grid size representing the neighborhood scale.

Results and Implications

The modeling results indicate that the UCP parameterization produces significant differences in the predicted mean and turbulent wind fields within the urban canopy, especially in areas characterized by a high density of tall buildings. The vertical profiles of wind speed and turbulence derived with UCP in MM5 are highly consistent with the results from wind tunnel studies. These results illustrate the importance of accounting for the urban structures in modeling the flow in urban areas. It provides a basis for more accurately resolving the magnitude and spatial details of the modeled air quality fields, especially for pollutant species that may have sharp spatial gradients that are important for human exposure assessment. By adding UCP into MM5, changes in spatial distributions from CMAQ were evident for several pollutant concentration fields including nitrogen oxides (NO_x), ozone, several PM species, as well as the toxic species formaldehyde and acetaldehyde. Furthermore, we found that the spatial representation of the concentration fields varied by pollutant species and was dependent upon grid cell size. Not surprisingly, for most pollutant species, decreasing grid cell size from 4 to 1.33 km accentuated the gradients of a pollutants concentration distribution pattern. For example, NO_x concentration features near dense mobile sources and point sources were considerably sharpened both in terms of horizontal gradients and concentration magnitude at 1.33 km resolution. Consequently, the simulations showed a corresponding decrease in ozone due to the effect of titration from the NO sources. Also, while the simulations for PM mass were relatively insensitive to increased grid resolution, its constituents did exhibit spatial texture. In addition, the simulation of both formaldehyde and acetaldehyde demonstrated that modeling these (and other toxic pollutants) at fine resolution (1.33 km) can lead to the identification of hot spots for toxic pollutants.

Research Collaboration and Publications	Contributions on developing and implementing the UCP parameterizations in MM5 were made by Dr. Avraham Lacser from the Israel Institute of Biological Research and by Dr. Sylvain Dupont, a Postdoctoral Fellow from University Corporation for Atmospheric Research. Collaboration with Dr. Jerry Herwehe of the Atmospheric Turbulence and Diffusion Division at the National Oceanic and Atmospheric Administration's Air Resources Laboratory is providing a basis for examining the variability in pollutant concentrations due to coupled turbulence and photochemistry. A report on this study has been produced towards meeting Annual Performance Measure 60 in support of GPRA Goal 1 (Clear Air), Objective 1.2 (Eliminate risks from air toxics). A manuscript has been prepared for submission to a peer-reviewed scientific journal, and a draft of this manuscript can be viewed at www.epa.gov/asmdnerl/nscale.pdf.
Future Research	Lidar scans and stereo photogrammetry data from airborne platforms are being used to develop high-resolution, three-dimensional representations of buildings and trees in a number of US cities. Such data can be incorporated into improved UCPs to further enhance the simulation of both the air flow and pollutant concentration patterns around urban areas. A set of detailed UCPs based on this approach is being developed for Houston, Texas and will be evaluated as part of this effort. Meanwhile, the development of methods to describe the within-grid variability of pollutant concentrations will continue, along with efforts to investigate the linkages to human exposure models. Eventually, this research should lead to better models that will allow predictive, as well as retrospective, assessments of human exposure and to address issues relevant to Homeland security.
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